BURIED TECTONIC STRUCTURES AND SEDIMENT THICKNESS VARIATIONS AT VALLES MARINERIS, MARS.
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SUMMARY

Variation of extension along the Valles Marineris grabens on Mars calculated using a simple structural model derived from morphology and topography data shows a low peak at the central troughs. If Valles Marineris is a single extensional system composed of linked faults, this peak should not reflect reality, indicating that the Valles Marineris structure is more complicated than what can be inferred from morphology and topography.

INTRODUCTION

Valles Marineris has been compared to terrestrial continental rifts for a long time [1-7]. Collapse above tension cracks has been recurrently proposed [8-10] as an alternative hypothesis, but is in contradiction with evidence of faceted spurs denoting large-scale normal faulting along the chasmata [11, 12], and with crack length-depth scaling ratio, which would require unrealistic crack depths [13].

Normal fault measurements on Earth has revealed that a linear relation exists between maximum fault displacement and fault length (e.g., [14]). A relation exists also between fault displacement and distance to fault centre [15]. Terrestrial continental rifts are composed of linked fault segments, which differs only slightly from the single fault case, so that the latter relation should apply [15, 16]. As a consequence, variation of extension along rifts is expected to increase roughly from rift ends toward rift centre.

Displacement-length scaling for the Valles Marineris border faults also fall within values typical of terrestrial grabens [14], suggesting that either the graben borders are composed of single normal faults, or they are composed of several linked faults. The latter is the most likely, and therefore, similar to terrestrial rifts, variation of extension is expected to increase from the western and eastern Valles Marineris ends towards the central grabens. The discrepancy between this theoretical pattern and the one that can be calculated from a structural Valles Marineris model obtained from morphologic and topographic analysis should reflect influence of unsuspected structural or sedimentary processes. Such calculations are reported and analysed here.

VARIATION OF EXTENSION

Independent attempts of calculating extension along the Valles Marineris grabens [17, 18] have been estimated through the stretching factor β, defined as the length of a profile taken perpendicular to the direction of extension divided by its length before extension [19]. Schultz [17] defined profile lengths from the width of the deformed zone within the Valles Marineris grabens, whether Mège and Masson [18] took constant profile length L=660 km, assuming that the actually deformed zone may have concentrated stress applied within an area defined by the Valles Marineris graben system length (2000 km) multiplied by its maximum width (660 km). Results from [18] are reported below; however, both methods led to similar results.

Stretching factor β has been calculated for 10 across-strike profiles (figure 1). Calculating β requires to estimate both fault throws and fault dips. Minimum values of border fault throws have been estimated to be equal to the height of the walls H. The profiles were selected in such a way that most landslide deposits could be avoided. When it was not possible, or when layered deposits mantle canyon floor, the thickness of these deposits were removed by replacing topography values by topography values in adjacent areas supposed to be representative of "normal" graben floor.

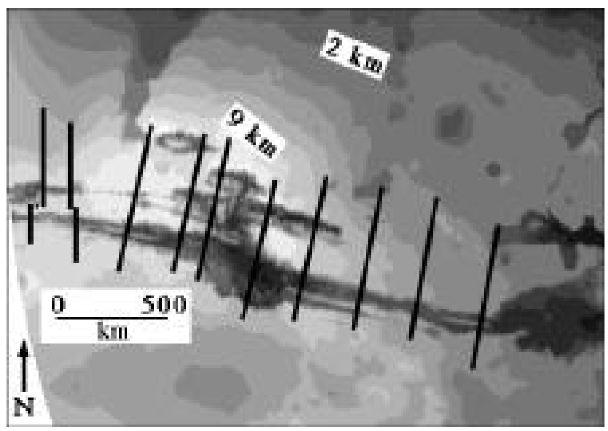

Figure 1 - Topographic map of Valles Marineris [20] showing location of the profiles used to estimate extension.

Fault throws should however be larger owing to the various deposits that mantle the entire graben system and are stratigraphically beneath the landslide and layered deposits. Two partly buried impact craters outcroping on graben floor suggest, from crater scaling laws, that the thickness of these sediments s should not exceed a few hundred meters [18]. Intense erosion of the central grabens suggests that sediment thickness variations may be large. From these arguments, fault throws have been taken between H and H+3 km.

Fault dips α have been taken between 60° (Anderson's model, [21]) and 90° (faulting from tension fracturing [22]), and block rotation has been accounted for using the method in [23]. After the calculations were done, the variation of fault dips was checked to be still consistent with the orientation of the least compressive stress [24], assumed to be permanently horizontal.

The stretching factor increases from the western Valles Marineris end to the central area, and then decreases eastwards; however, there is a low extension peak centred on the central grabens (figure 2). Another feature is a another, slight but clear, increase of extension eastward east of 60°E. The latter is due to the development of Gangis Chasma at the eastern end of the graben system, which balances the general eastwards decrease of border fault throws in the other grabens. Whatever the fault throws and dips, strain is always very low ($\beta <$ 1.1), probably lower than strain in African rifts (e.g., [18]). Similar values have been found by Schultz [17].

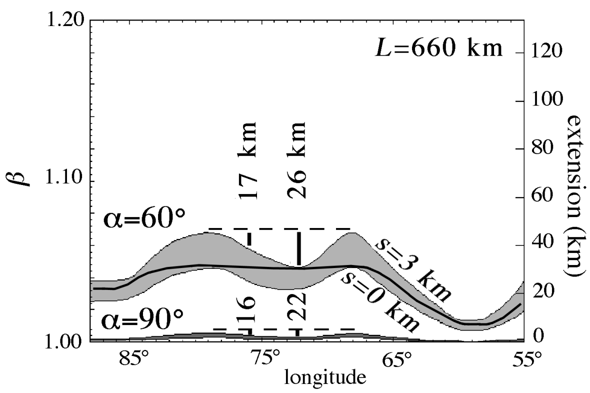

Figure 2 - Variation of stretching (β) and extension (km) along Valles Marineris.

DISCUSSION

Two explanations can be considered for the existence of the low peak in the curves displayed on figure 2. Centrifugal increase of extension in Valles Marineris is possible when the mean sediment thickness is close to 0 km on both sides of the central graben system, and at least 3 km in the middle (e.g., heavy line between curves s=0 km and s=3 km). Alternatively, the total fault throws accounted for in the extension model may have been underestimated in the central graben. Accounting for additional vertical offsets would help smoothing the low extension peak at the centre of the graben system. Detailed results for the two central profiles show that at least 16 to 26 km of additional vertical fault throw in the direction of least principal strain are required on the two centralmost profiles to obtain constant extension along the central Valles Marineris grabens, depending on fault dips (figure 2). These values, like those obtained if variations of sediment thickness are considered, are minimum values because they allow central extension *not to be less than* extension on both sides of the rift; still higher values are required to actually obtain a *positive extension peak* at the rift centre. Which origin for the low extension peak is the right one is hard to determine; it is likely that both sediment thickness variations and buried extensional structures exist.

Any profile cuts across areas where the main border faults were destroyed by erosional processes. Thus, if additional structures exist in the central grabens that were not accounted for in the structural model, they should be distributed as e.g. horsts and grabens within the currently observed grabens, and buried by more recent sediments. Such partly buried horsts are observed in Coprates Chasma, close to Melas Chasma. Although a Valles Marineris structural model resulting from topography and morphology analysis may be a good first approximation of reality, comparison to geometry of grabens in terrestrial rifts clearly suggests that the detailed structural geometry of Valles Marineris is likely to be, indeed, much more complicated.

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